

## Monetary Fundamental-Based Exchange Rate Model in Iran: Applying a MS-TVTP Approach

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### **Abstract**

The main purpose of this article is to analyze exchange rate behavior based on monetary fundamentals in the context of Iranian economy over the period 1990:2 to 2014:3. To do so, two monetary exchange rate models is investigated, the first by regarding interest rate differential as a monetary variable, and the second one regardless of interest rate differential as a monetary variable. Also, in both cases, effective factors on exchange rate regime shifting are examined in Time-Varying Transition Probabilities Markov Switching Model (TVTP MSM). The main results indicate that interest rate differential model is not suitable to explain exchange rate behavior in Iran. Furthermore, Markov Switching Time-Varying Transition Probabilities model in comparison with Markov Switching Fixed Transition Probabilities has a better performance in analyzing exchange rate behavior. In addition, changes in real oil price are a main determiner of probability of regime switching.

**Keywords:** Exchange Rate Behavior, Monetary Fundamentals, Markov Switching Model, Iran Economy.

**JEL Classification:** C24, F37, F41.

### **1. Introduction**

Explaining exchange rate and its management in developing countries, which have often managed the exchange rate system, is important. After Bertton Woods's system, when a managed floating exchange rate system was approved, it was observed that the flow approach to exchange rate had lost its power. Hence, a group of international

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economists, who in terms of Whitman (1975) were global monetary economists, came to work and introduced a new approach. The mechanism of the group's approach toward the exchange rate was that international flows of resources resulting from the imbalance of payments could be through their effects on the national money supply and price level, and therefore, the effect on the trade balance creates this balance automatically. Thus, the monetary model of exchange rate determination was released first by Polak (1957), and later by Frenkel (1976) and Bilson (1978). The most important and most fundamental question investigated by monetary models studies is how monetary variables affect the fluctuation of exchange rate. According to Johnson (1977), the distinction between Monetary Approach to Exchange Rate (MAER) and other approaches is that it import stocks as well as current expenditures to the adjustment process, and thus imbalance of payment is temporary and contingent for domestic monetary policy. So, on the basis of monetary approach, reducing resources shall reduce the amount of money in the next periods. This leads to a reduction in the level of domestic expenditure in the next periods, and the process continues until in equilibrium, the equality between imports and exports as well as between spending and revenue get generated. As Frenkel (1976) suggests, it should be noted that the MAER does not suggest that the exchange rate is determined just in the money market (or asset market), or only stockade considerations are important. Clearly, exchange rate like other prices is determined in general equilibrium, and through the mutual interaction of stocks and flows' conditions.

Usually monetary model is presented as a model for the two countries and two kinds of money in which all goods are tradable, and the law of one price, as well as assumption of the Uncovered Interest Parity (UIP), as an application of monetary model, is approved. According to Boughton (1988), reduced-form test of monetary approach, will be as the equation 1:

$$e = (m - m^*) - \beta_1(y - y^*) + \beta_2 E(\Delta p - \Delta p^*) - \left(\frac{1}{\beta_4} - \beta_2\right)(r - r^*) + \left(\frac{\beta_3}{\beta_4}\right)k \quad (1)$$

In which, m, p and y stand for the logarithm of money stock, the

price and the real production. Also,  $r$  is the real interest rate,  $k$  is the cumulative balance on private capital account, and  $e$  is the logarithm of the nominal exchange rate. In addition,  $E$  represents the expected values, and the asterisk (\*) indicates the foreign values for these variables. Monetary approach can be tested through stability and trust coefficients of the above equation. In other words, it is tested whether  $\beta_3 = 0$  or not.

Numerous studies have been done in which different monetary fundamentals, that can affect the exchange rate, have been probed. In most of them, the supply of money, money stock, currency in circulation, or liquidity (see Flood and Marion, 1983; Nakhjavani, 1993; Flood and Rose, 1995; Dargahi, 1999; Dargahi and Gachlou, 2002; Bastanzad, 2003; Madani Esfahani, 2003; Abrishami and Rahimi, 2004; Ehrmann and Fratzcher, 2005; Sabbagh Kermani and Shaghaghi Shahri, 2005; Akhbari, 2006; Horry et al., 2006; Mozayeni, 2006; Bitzenis and Marangos, 2007; Uz and Ketenci, 2008; Kazerooni et al., 2010; Juntila and Korhonen, 2011; Eslamloueyan, 2011; Jalaei Esfandabadi et al., 2013; Bekiros, 2014; Wu 2015; Asgharpoor et al., 2015), and interest rate (see Flood and Marion, 1983; Lim, 1992; Nakhjavani, 1993; Pazarbacioglu and Otker, 1997; Bastanzad, 2003; Frömmel et al., 2005; Akhbari, 2006; Bitzenis and Marangos, 2007; Uz and Ketenci, 2008; Asgharpoor et al., 2009; Apergis et al., 2012; Bekiros, 2014; Yin and Li, 2014; Wu, 2015; Bouraoui and Phisuthiwatcharavong, 2015) are used as the basis for influencing the exchange rate. Also, production, Gross Domestic Product (GDP), or national income (see Flood and Marion, 1983; Nakhjavani, 1993; Flood and Rose, 1995; Dargahi, 1999; Bastanzad, 2003; Akhbari, 2006; Uz and Ketenci, 2008; Rubaszek and Rawdonowicz, 2009; Asgharpoor et al., 2009; Kazerooni et al., 2010; Yin and Li, 2014; Bouraoui and phisuthiwatcharavong, 2015; Wu, 2015) are introduced as the monetary fundamentals, along with other fundamentals which are effective on the exchange rate. Accordingly, there are differences in illustrating the pattern of monetary exchange rates. A generalized monetary model is the one Frankel (1979) illustrates. He suggests Real Interest Differential (RID) which is indicated in the equation 2:

$$\Delta e_t = \alpha + \beta_1(\Delta m_t - \Delta m_t^*) + \beta_2(\Delta y_t - \Delta y_t^*) + \beta_3(\Delta s i_t - \Delta s i_t^*) + \beta_4(\Delta l i_t - \Delta l i_t^*) + \varepsilon_t \quad (2)$$

In which  $m_t$  is the logarithm of money supply at time  $t$ ,  $y_t$  is the logarithm of the national production at time  $t$ ,  $s i_t$  is the short-term interest rate at time  $t$ , and  $l i_t$  is the long-term interest rate at time  $t$ . According to Wu (2015), interest rate differential (IRD), despite its simplicity, has many assumptions. Among the postulations of this model, there are complete substitutions between domestic and foreign assets, and free adjustments of exchange rate for the equality of supply and demand in the foreign exchange market. This pattern is not easily applied in all countries, and coefficient signs are not in accordance with the expectation from the model. In fact, any money has a unique economic condition; so, monetary treatments are not the same, and perhaps this is why Meese and Rogoff (1983) argue that changes in exchange rate cannot be predicted by fundamentals in under a year prospects. Another important issue about the behavior of exchange rate and monetary fundamentals is that there is a nonlinear relationship between them and economists such as Qi and Wu (2003), Frömmel et al. (2005), Junttila Korhonen (2011), Tang and Zhou (2013) and Wu (2015) clarify that. Among nonlinear models, Markov Switching Model for its advantages rather than others is suitable for experimental works. In general, Markov switching models are divided in three categories of Fixed Transition Probabilities Markov Switching Model (FTP MSM), Time-Varying Transition Probabilities Markov Switching Model (TVTP MSM), and Markov Switching Vector Autoregressive (MSVAR).

In Iran as a developing country in which consumption and investment are highly dependent on its foreign sector, it is essential and critical to identify the factors affecting the exchange rate, as well as distinguish factors affecting the probability of changes in exchange rate system. Therefore, this paper will study this issue using MS-TVTP model as the main contribution of the study.

The remainder of this paper is organized as follows. In section 2 we formulate the model. Section 3 presents the empirical results. Final remarks are given in Section 4.

## 2. The Model

The model of this study is based on that proposed by Wu (2015), considering monetary variables affecting the exchange rate. Thus, the model can be formulated as shown in equation 3:

$$\Delta e_t = \alpha_{s_j} + \beta_{1s_j}(\Delta m_t - \Delta m^*_t) + \beta_{2s_j}(\Delta y_t - \Delta y^*_t) + \beta_{3s_j}(\Delta si_t - \Delta si^*_t) + \beta_{4s_j}(\Delta li_t - \Delta li^*_t) + \beta_{5s_j}p_t^{oil} + \varepsilon_{ts_j} \quad (3)$$

In which,  $e$  is the logarithm of nominal exchange rate (the price of one USD in terms of Rials),  $m_t$  is the logarithm of money supply at time  $t$ ,  $y_t$  is the logarithm of industrial production at time  $t$ ,  $si_t$  is the short-term interest rate at time  $t$ ,  $li_t$  is the long-term interest rate at time  $t$ , and  $p_t^{oil}$  is the logarithm of real global oil price at time  $t$ .

## 3. Empirical Results

The main questions that this paper tries to answer are:

1. Does the behavior of exchange rate in Iran is based on IRD accommodating other monetary variables?
2. What are the factors affecting regime switch?

Our empirical findings are presented in three subsections. The first subsection investigates the monetary model considering IRD in the two estimation models of Fixed Transition Probabilities Markov Switching Model (FTP MSM) and Time-Varying Transition Probabilities Markov Switching Model (TVTP MSM). The second subsection investigates the monetary model regardless of IRD in the two estimation models of FTP MSM and TVTP MSM. In the third subsection, the two models are compared, and their accuracy for Iran's economy are explained.

To have the best model, we should introduce the logarithmic change of the money supply as the switching variable, and the changes in logarithm of real global oil price should be chosen as a factor affecting the probability of transition. It should be noted that this finding is based on previous studies and theories. In fact, based on the monetary model of determining exchange rate, the money supply is an important factor in determining the exchange rate and the exchange system. In Iran, there are studies that have argued that the real price of oil affects the exchange rate (see Dargahi, 1999; Dargahi and

Gachlou, 2002; Mirtahami, 2004; Rezaei and Molaei, 2005; Sabbagh Kermani and Shaghaghi Shahri, 2005; Hashempour, 2011; Asgharpoor et al., 2015); but no domestic or foreign studies have been done that consider the real price of oil as a factor affecting the regime switches. However, for the importance of the role of this factor in the exchange rate, it can be tested as the factor affecting the regime switches, and it can be seen that among the different variables under consideration, such as logarithmic change of the money supply, logarithmic change of the industrial production, changes in short-term interest rate, and changes in long-term interest rate, logarithmic change of real price of oil has been the determining factor of regime switches.

In this study, two regimes of fixed exchange rate and the (managed) floating exchange rate are considered. Also, the estimation of the model is presented, using the two states of TVTP MSM and FTP MSM. Furthermore, quarterly data over the period 1990:2–2014:1 using time series data of the Central Bank, the World Bank, the Federal Reserve, and U.S. Energy Information are used.

Before estimating Markov switching model, in order to ensure the integrity of the nonlinear model to analyze the behavior of the exchange rate, it has been used the likelihood ratio test. Results of this test for the two models have been indicated in tables 1 and 2.

**Table 1: Likelihood Ratio Test Results in Monetary Model Considering IRD**

Log Likelihood of Linear Model	Log Likelihood of Non-Linear Model	Likelihood Ratio Statistic	$\chi^2$ Critical Test at 95% Confidence Level with Freedom Degree of 6
-322.7720	27.7720	700.9765	1.63

**Table 2: Likelihood Ratio Test Results in Monetary Model Regardless of IRD**

Log Likelihood of Linear Model	Log Likelihood of Non-Linear Model	Likelihood Ratio Statistic	$\chi^2$ Critical Test at 95% Confidence Level with Freedom Degree of 6
-323.4219	15.09130	677.0064	1.145476

Source: Authors compilation

**Table 3: Results of Monetary Model Considering IRD Using Markov Switching Model of FTP and TVTP**

Explanatory Variable	Estimation with FTP-MSM			Estimation with TVTP-MSM			Expected Sign
	Coefficient	SD	Significant Level	Coefficient	SD	Significant Level	
Intercept in Regime 1	11.11	6.2	0.736	5.79	3.78	0.1256	n. a.
Intercept in Regime 2	0.08	0.03	0.0024	0.05	0.005	0.000	
Logarithmic Change of the Money Supply in Regime 1	-373.1	737.1	0.6128	-144.86	524.36	0.7823	>0
Logarithmic Change of the Money Supply in Regime 2	-6.5	4.5	0.1511	-4.96	0.73	0.000	
Logarithmic Change of Industrial Production	-10.6	3.1	0.0007	-2.5	0.72	0.0005	<0
Changes in Short-Run Interest Rate	0.028	0.028	0.3179	-0.018	0.005	0.0001	<0
Changes in Long-Run Interest Rate	-0.29	0.066	0.000	-0.036	0.013	0.0047	>0
Logarithmic Change of Real Global Oil Price	0.1	0.2	0.6143	0.033	0.032	0.3035	>0
Logarithm of SD in Regime 1	2.8	0.18	0.000	2.56	0.14	0.000	
Logarithm of SD in Regime 2	-2.24	0.1	0.000	-4.12	0.12	0.000	
Transition Matrix	Regime1	0.82	0.18	Regime 1	~0.9	~0.1	
	Regime2	0.05	0.95	Regime 2	~0.05	~0.95	
		Regime 1	Regime 2		Regime1	Regime 2	
Expected Durations for Regime 1		5.66			9.99		
Expected Durations for Regime 2		21.93			27.6		
Akaike Info Criterion		0.877			-0.29		

Source: Authors compilation

### 1.3 Monetary Model with the Presence of IRD

In this subsection, the equation 3 will be explored. Findings are summarized in Table 3.

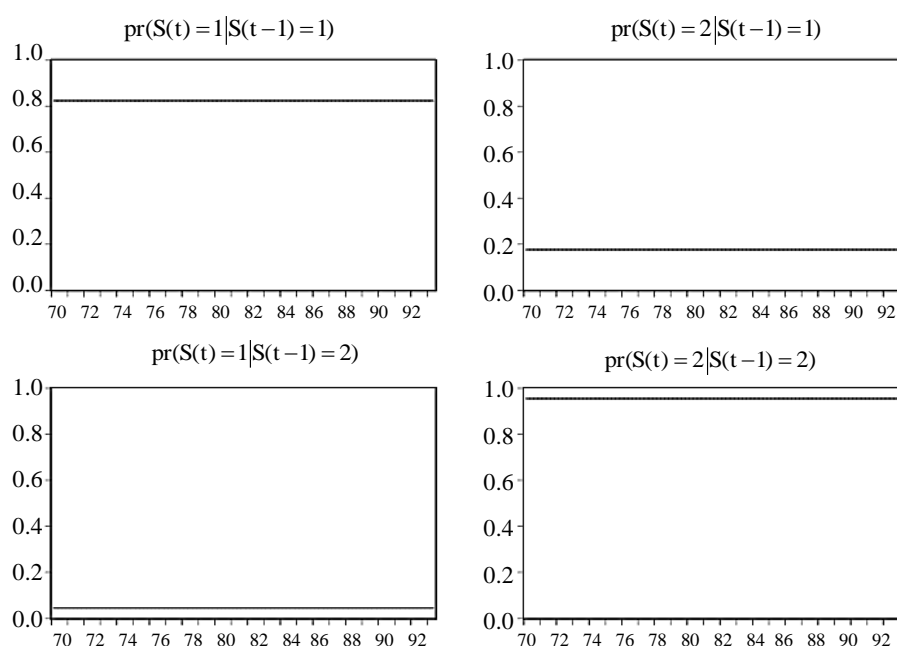
As can be seen, none of intercept and logarithm changes in money supply in regime 1 are significant in the level of 5 percent; it means that the pattern of monetary model of exchange rate in regime 1, which is the fixed exchange rate regime, is not approved. However, it is expected the monetary model in the fixed exchange rate regime not to be approved; because according to the theory, monetary model can be applicable for (managed) floating exchange rate regime. Based on the monetary model of determining the exchange rate, we expect the coefficient sign of logarithmic change of the money supply to be positive, and the coefficient sign of logarithmic change of industrial production to be negative. Here, the coefficient sign of logarithmic change of industrial production is as expected, but the coefficient sign of logarithmic change of the money supply is contrary to our expectation. It is not unexpected the coefficient sign of logarithmic change of the money supply to be negative; because in Iran, there is deficit in most periods, and deficit is inflationary. In order to adjust deficit, between issuing security and money, governments chooses the second which results in intensification of inflation. On the other hand, it increases the nominal wage of workers to maintain their purchasing power, but for the reason of people's money illusion, demands for consuming goods increases, and these results in increasing imports and reducing exchange rate. Also, according to Wu (2015) it is expected the coefficient sign of changes in short-term interest rate to be negative, and the coefficient sign of changes in long-term interest rate to be positive. Here in FTP MSM, coefficient sign of changes in short-term interest rate is contrary to expectation, but in TVTP MSM, this sign is as expected. Coefficient sign of changes in long-term interest rate is as expected in both FTP MSM and TVTP MSM. It is expected the changes in logarithm of real oil price to be positive; because increasing the oil price results in increasing the value of exports, and since the changes in exports is in the same direction as the changes in exchange rate, the exchange rate increases. So, the changes in exchange rate and the changes in oil price are in the same direction. As can be seen, the coefficient sign of logarithm of real oil



price is as expected in both FTP MSM and TVTP MSM. Furthermore, it can be seen that all coefficients, except the coefficient of logarithm of real oil price in both FTP MSM and TVTP MSM are significant in the level of 5 percent. Also, the coefficient of logarithm of short-term interest rate in FTP MSM is not significant in the level of 5 percent.

As can be seen, the significance of coefficients in TVTP MSM is better than FTP MSM. Another finding is that regimes 1 and 2 in both FTP MSM and TVTP MSM are sorbent. But the expected duration of delay in the regimes 1 and 2 based on FTP MSM is estimated less than TVTP MSM. According to the statistical information in the field of Iran's economy, the result of TVTP MSM is more consonance with reality of Iran's economy.

To better understand the difference between the two FTP MSM and TVTP MSM, transition probability matrix is provided in the graphs of two Figures 1 and 2.



**Figure 1: Transition Probability Matrix in FTP MSM**

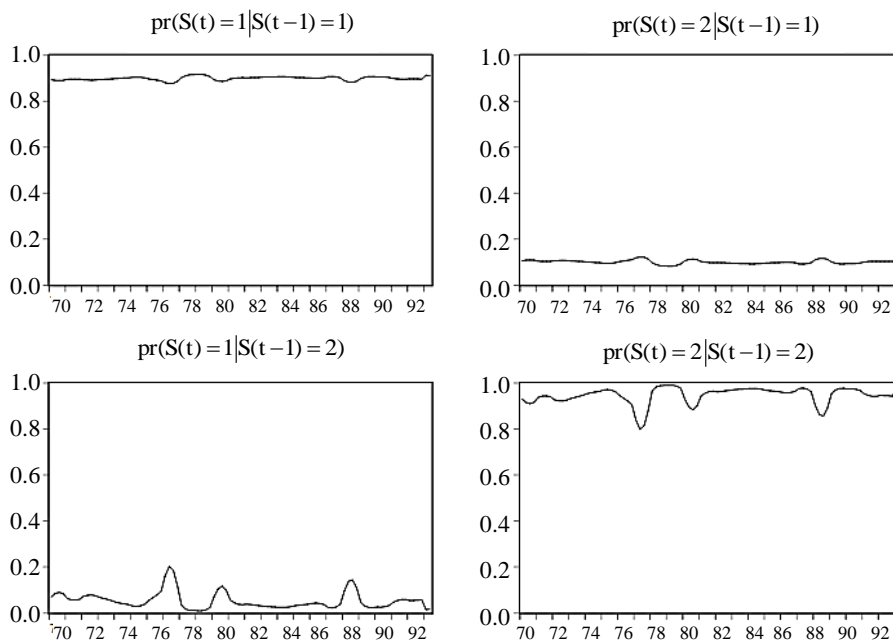


Figure 2: Transition Probability Matrix in TVTP MSM

As can be seen, in TVTP MSM, probability of delay in a regime or switching to another one, does not have a linear form and behave nonlinearly.

It should be noted that to certify the accuracy of the results, residuals of the estimation were tested. Residual series achieved by FTP MSM and TVTP MSM are provided in Figures 3 and 4.

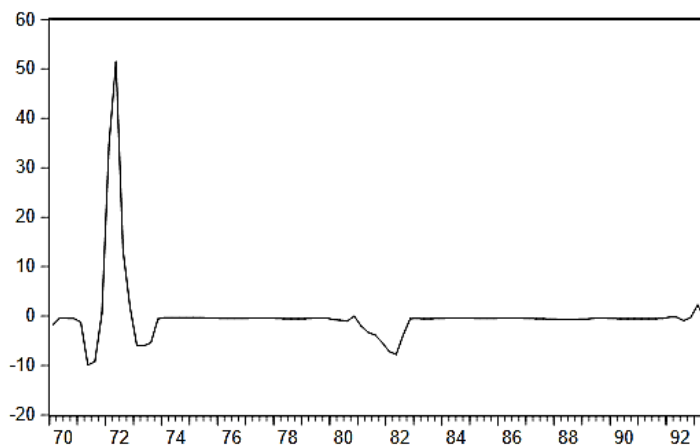


Figure 3: Residuals Gained from TVTP MSM

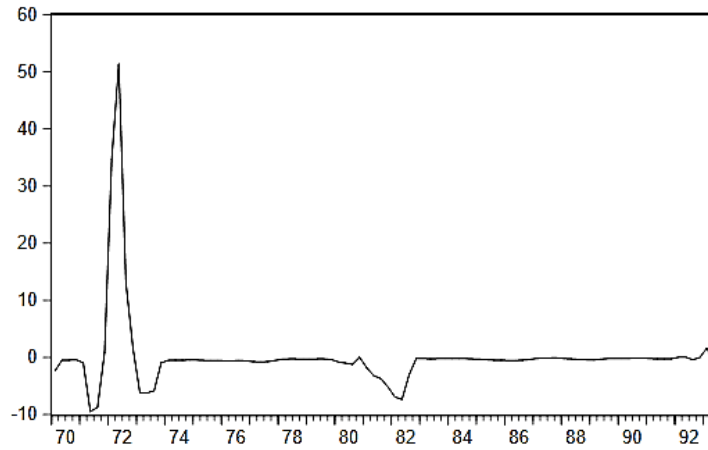


Figure 4: Residuals Gained from FTP MSM

Also, to examine the stationarity of these series, unit root tests were performed and t-statistics of 62.3 for FTP MSM and 68.3 for TVTP MSM were reported. That represented the stationarity of these series.

In the next subsection, monetary model is investigated regardless of IRD.

### 2.3 Monetary Model regardless of IRD

In this subsection, the equation 4 is examined.

$$\Delta e_t = \alpha_{s_j} + \beta_{1s_j}(\Delta m_t - \Delta m^*_t) + \beta_{2s_j}(\Delta y_t - \Delta y^*_t) + \beta_{3s_j}p_t^{oil} + \varepsilon_{ts_j} \quad (4)$$

The results of this model are summarized in Table 4.

Table 4: Results of Monetary Model Regardless of IRD Using Markov Switching Model of FTP and TVTP

Explanatory Variable	Estimation with FTP-MSM			Estimation with TVTP-MSM			Expected Sign
	Coefficient	SD	Significant Level	Coefficient	SD	Significant Level	
Intercept in Regime 1	6.2	3.9	0.1108	6.33	3.99	0.1132	n. a.
Intercept in Regime 2	0.03	0.006	0.000	0.03	0.006	0.000	
Logarithmic Change of the Money Supply in Regime 1	-175.3	529.2	0.7405	-182.95	540.4	0.7350	>0

**Table 4: Results of Monetary Model Regardless of IRD Using Markov Switching Model of FTP and TVTP**

Logarithmic Change of the Money Supply in Regime 2	-2.9	0.93	0.002	-2.9	0.97	0.0027	
Logarithmic Change of Industrial Production	-3.63	0.94	0.0001	-3.58	0.97	0.0002	<0
Logarithmic Change of Real Global Oil Price	0.073	0.042	0.0834	0.08	0.04	0.0736	>0
Logarithm of SD in Regime 1	2.6	0.14	0.000	2.6	0.14	0.000	
Logarithm of SD in Regime 2	-3.8	0.13	0.000	-3.8	0.13	0.000	
Transition Matrix	Regime 1	0.9	0.1	Regime 1	~0.87	~0.13	
	Regime 2	0.05	0.95	Regime 2	~0.06	~0.94	
		Regime 1	Regime 2		Regime 1	Regime 2	
Expected Durations for Regime 1		9.5			9.5		
Expected Durations for Regime 2		19.4			26.48		
Akaike Info Criterion		0.087			-0.065		

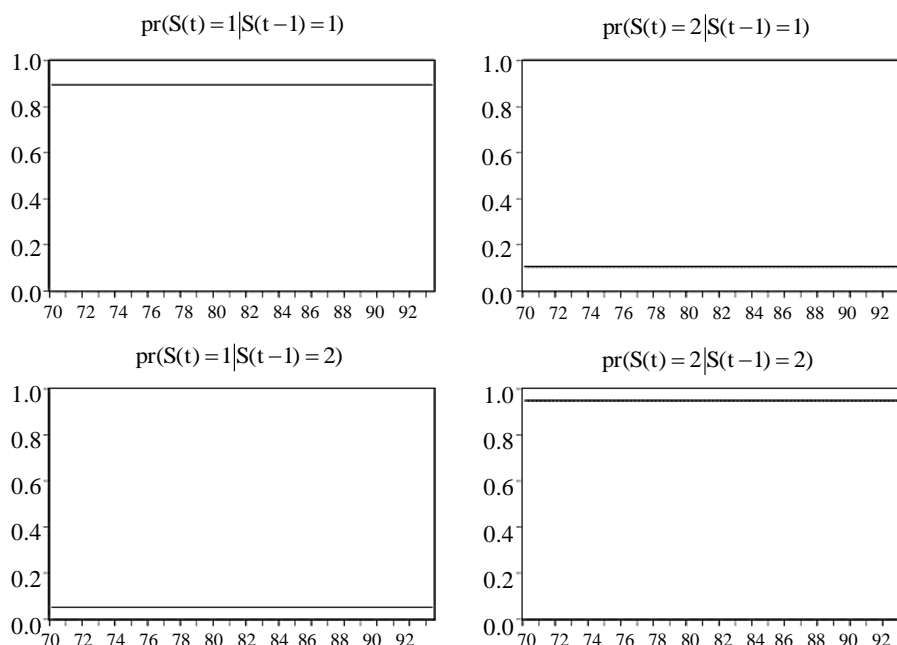
**Source:** Authors compilation

As can be seen, both intercept and logarithmic change of the money supply are not significant in the level of 5 percent that indicates not approving of monetary model of determining the exchange rate in the fixed exchange rate regime. Based on the monetary model of exchange rate, we expect the coefficient sign of logarithmic change of money supply to be positive, and the coefficient sign of logarithmic change of industry product to be negative; but here, the coefficient sign of logarithmic change of industrial product is as expected, while the coefficient sign of logarithmic change of money supply is contrary to expectation. Based on the reasons stated in the previous subsection,

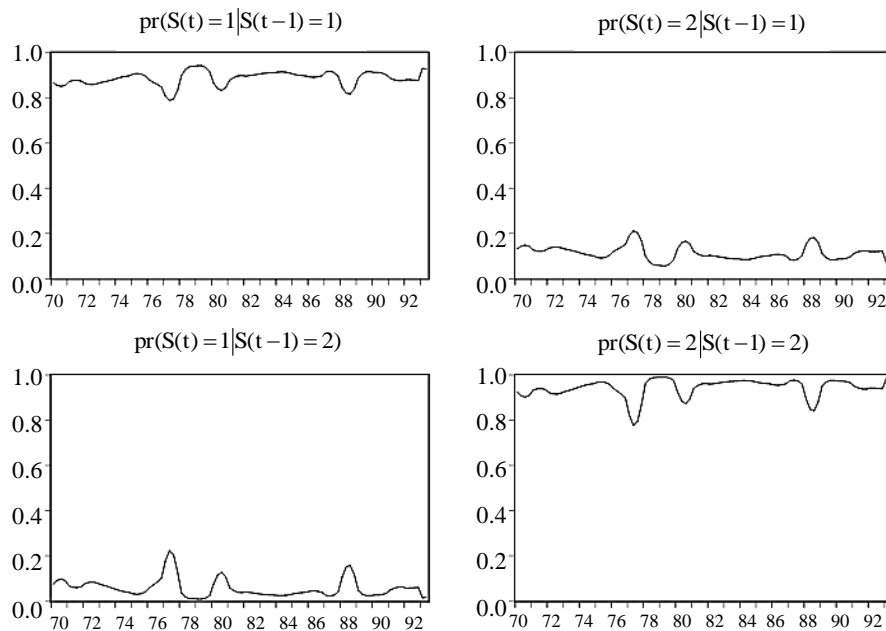
it is not unexpected the sign of logarithmic change of money supply to be negative. Also, it is expected the sign of logarithmic change of real price of oil to be positive, which in both FTP MSM and TVTP MSM is positive. Furthermore, it can be seen that all coefficients except the coefficient of logarithmic change of oil real price in both FTP MSM and TVTP MSM are significant in the level of 5 percent. Also, the coefficient of changes in the log of real price of oil in both FTP MSM and TVTP MSM is significant in the level of 10 percent.

As can be observed, the significance of coefficients in TVTP MSM is better than FTP MSM. Another result is that in the two FTP MSM and TVTP MSM, both regimes 1 and 2 are sorbent; but the expected delay in regimes 1 and 2 based on FTP MSM is less than that of TVTP MSM. According to statistical data in the field of Iran economy, it is observed that the result of TVTP MSM is more consonant with the reality of Iran economy.

Like last subsection, in order to apperceive the difference between the two Fixed and FTP MSM and TVTP MSM, transition probability matrixes is presented as graphs in figures 5 and 6.

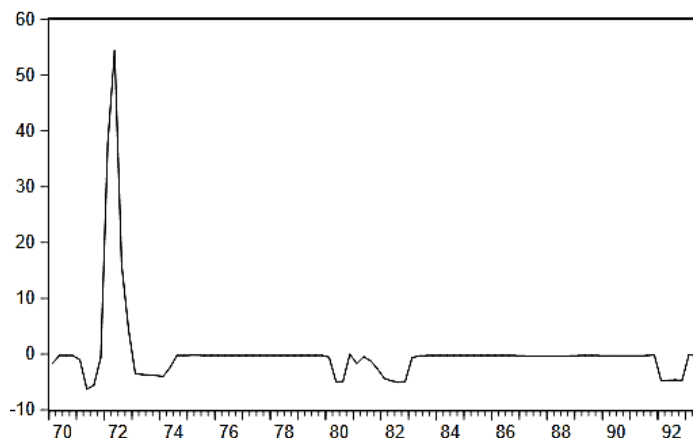


**Figure 5: Transition Probability Matrixes in FTP MSM**

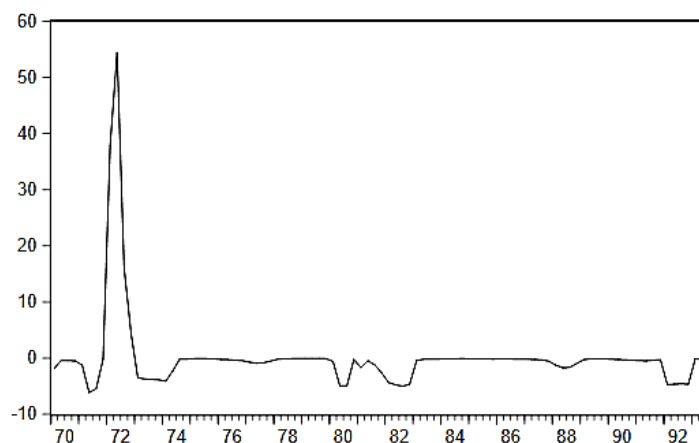


**Figure 6: Transition Probability Matrix in TVTP MSM**

Like the last subsection, residuals of the estimation were tested to ensure that the results are accurate. Residual series gained from FTP MSM and TVTP MSM are provided in Figures 7 and 8.



**Figure 7: Residuals Gained from FTP MSM**



**Figure 8: Residuals Gained from TVTP MSM**

Also, in order to examine the stationary of these series, unit root test was performed, and t-statistics of  $-4.63$  for TVTP MSM, and  $-4.61$  for MSTVTP were reported which shows the stationary of these series.

### 3.3 Comparing the Two Models

In comparing the two models, it is observed that the regression without IRD model is better than the regression with IRD, which shows IRD model is not so accurate in Iran. Also, in the model without considering IRD, coefficients are more significant, and on average, the logarithm of standard deviation of these two, is less than the logarithm of standard deviation of the model with IRD. One of the similarities between the two models is that in both, the regime 1 is non-significant which shows non-approval of monetary model in fixed exchange rate system. On average, the regime switch point dates back to the years 1993–1994, when different economic revolutions have been observed.

One of the important changes related to the subject is that preparation for the liberalization of the exchange rate began in 1989 and continued until 1993; so, this year is when exchange rate has been changed from fixed to managed floating system. Accordingly, the time of change the regime is in the years 1993–1994. Another similarity between these models is that the sign of logarithmic change of money supply is contrary to expectation which comes from Iran's

economic structure. Also, the sign of logarithmic change of industrial production and logarithmic change of the real price of oil in both models is the same as expected. Another point is that the logarithmic change of the real price of oil has been an influential factor in the regimes' transition. The reason that logarithmic change of the real price of oil affects the probability of regime transition is that for example, over the period 1989–1993 by creating positive momentum in macroeconomic demand, and according to the necessity of providing financial sources for investment, it was planned to produce more oil and create new capacities. This resulted in 9 and 5.7 percent growth rate of value-added and increasing the oil investments during this period. In fact, increasing the investments of oil industry results in decrease of oil extraction cost and breakeven of oil extraction. In this case, by rising of global oil prices, the profit from the sale of oil increases. This would lead to the import of currency sources to the inside. Due to the nature of some sectors of the economy which is such that there is no need to invest heavily to produce more, if the exchange system of the country remains constant, these sectors will face with uncommon profit, which results in uneven development of different sectors of economy. To avoid that, it is necessary to modify the regime to managed floating exchange rate regime. So, the change in oil prices is an important factor in the probability of regime switch. The last point of the similarity between the two is that investigating the model of exchange rate using TVTP MSM provides more reliable results and a better regression model.

#### **4. Conclusion**

Exchange rate and the factors influencing its behavior in developing countries, is important. Since most of these countries are considered as small open countries and price takers, keeping their economies from external shocks inflicts is important. Hence, according to the point that Iran economy is developing, and Islamic Republic of Iran is a small open country, studying its exchange rate behavior is worthy to plan more suitably for the economy. Therefore, in this study, we investigated the behavior of exchange rate on the basis of monetary fundamentals using Markov switching models.

First, an introduction was presented to some monetary models and



its mechanism, and then by reviewing the literature, it was concluded that monetary model has been succeeded in explaining the behavior of the exchange rate, and there is a nonlinear relationship in the behavior of the exchange rate based on monetary fundamentals. Another result is that money supply, interest rate, national income or product, etc. are the effective factors in exchange rate behavior. Then the research model was discussed in detail, and empirical results were delivered regarding and regardless of IRD. It was observed that in general, explaining the changes in the exchange rate in Iran considering IRD is not successful. Also, examining the factor affecting the probability of regime switch showed that global oil price is the most important factor which affects the probability of the change of exchange rate regime in Iran. So, using TVTP MSM, and considering the global oil price as a factor affecting the probability of regime transition, it was observed that the designed regression model is more suitable rather than the state in which FTP MSM is considered. Therefore, we may conclude that the probability of regime transition is not constant and varies over time. So, in order to examine the behavior of the exchange rate, it is better to use nonlinear TVTP MSM.

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